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METHODS AND COSTS OF MINING ZINC-LEAD ORES AT THE PEND OREILLE MINES & METALS CO., METALINE FALLS, WASH.

BY

CHARLES A. R. LAMBLY

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METHODS AND COSTS OF MINING ZINC-LEAD ORES AT THE PEND OREILLE MINES & METALS CO., METALINE FALLS, WASH.[1]

By Charles A. R. Lambly[2]

INTRODUCTION

This paper, which describes the mining practices of the Pend Oreille Mines & Metals Co. at Metaline Falls, Wash., is one of a series being prepared by the Bureau of Mines on mining practices, methods, and costs in various mining districts of the United States.

ACKNOWLEDGMENTS

Acknowledgment is made to L. P. Larson, president, and Jens Jensen, secretary, of the Pend Oreille Mines & Metals Co. for permission to publish this paper. Information was supplied by E. Berglund, mine superintendent; Earl Miller, chief engineer; Lynn Kinney, John Currie, and Wally Frick, engineers; Arthur Newman, chief clerk; and Jack Crampton, assayer.

LOCATION

The Pend Oreille Mines & Metals Co. operates in the Metaline mining district of Pend Oreille County, northeastern Washington. The company properties are on both sides of the Pend Oreille River, north of the town of Metaline Falls. Metaline Falls is approximately 110 miles north of Spokane, Wash., and 11 miles south of the Canadian border.

HISTORY

Lead deposits in the Metaline district have been known for the past 60 years. In 1904 L. P. Larson started prospecting there, and in 1910 he interested the Lehigh Portland Cement Co., of Allentown, Pa., in a limestone and shale deposit, which prompted them to erect a large cement plant at Metaline Falls. Mr. Larson gave the townsite of Metaline Falls to the State of Washington in the same year. Prospecting for zinc-lead ore was carried on during this period; a mill employing table concentration was erected in 1917 and was operated for a few months. For the next 10 years there was little activity, but in 1927 the old Pend Oreille mill was rebuilt as a flotation plant and operated for 6 months on surface ores. The Pend Oreille Mines & Metals Co. began development in the area in 1928 and discovered promising ore bodies. The mill operated intermittently from 1930 to 1934. Development continued, and in 1935 construction of the present plant was begun; it has been operating continuously since January 1, 1936.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7152."

[2] General superintendent, Pend Oreille Mines & Metals Co., and one of the consulting engineers, Bureau of Mines, U. S. Department of the Interior.

GEOLOGY

> The replacement ore bodies of the Metaline zinc-lead district in northeastern Washington are limited to the greatly disturbed fault block through which the Pend Oreille River flows and are associated with the major faults but are not in them. They are mostly near the top of the Metaline limestone, of Middle Cambrian age, and below black Ordovician slate. The ores are generally in jasperoid and are surrounded by a shell of crystalline dolomite. Outside of the dolomite is a shell of coarse-grained calcite that in places was deposited along solution channels long distances from known ore bodies. Jasperoid, crystalline dolomite, and, to a less extent, coarse-grained calcite are therefore favorable but not infallible signs of the presence of ore near by. The Metaline limestone was dolomitized regionally before the ore was introduced, and this early dolomitization is independent of the ore.3/

In the area of the Pend Oreille Mines & Metals Co. operations the ore bed lies 200 to 400 feet below the surface. The gravel and sand overburden usually ranges from 10 to 150 feet, but in some places it is 250 feet deep. The shale formation over the ore horizon ranges from nothing to 200 feet in thickness. The favorable lime horizon is approximately 200 feet thick, and the commercial ore occurs on or very near the footwall of the favorable lime bed in the Metaline limestones. The ore is in large, irregular, adjoining blocks close to the bottom of the favorable limestone beds. In most places the footwall is a massive gray limestone underlying the limestone beds. The general dip of the ore beds is 20° to the north and east.

PHYSICAL CHARACTERISTICS OF ORE AND ENCLOSING ROCKS

The limestone beds in which the ore bodies occur are very siliceous, brecciated, and faulted. The explored area is approximately 6,000 feet along the dip and 3,000 feet along the strike. The known commercial ore bodies in this area have an approximate length of 5,000 feet and a maximum width of 700 feet. The length, width, thickness, and dip of the ore horizon usually are controlled by faults whose displacements are from a few inches to several hundred feet. The commercial ore ranges in thickness from a few feet up to 100 feet; this change in thickness may take place within a very few feet horizontally, usually as a result of faulting.

3/ Park, C. F., Jr., Dolomite and Jasperoid in the Metaline District, Northeastern Washington: Econ. Geol., vol. 33, November 1938, p. 709.

The ore horizon, although badly faulted and fractured, is very solid. The walls and backs of mined stopes stand with very little sloughing. Stopes as much as 300 feet in length, 100 feet in width, and 120 feet in height have been opened.

Large blocks of calcite occur in the ore horizon and usually are completely surrounded with ore. These calcite blocks are from a few inches to 200 feet wide. Large blocks of low-grade ores (that is, up to 2 percent zinc) occur in the ore horizon. These low-grade sections are similar in size to the calcite blocks. The calcite and low-grade sections are used wherever possible for pillars and wall supports.

In places in the ore horizon are large open caves ranging from a few feet to 120 feet in length, 110 feet in width, and 15 feet in height. The backs of the caves usually are fairly sound, and are lined with asbestos known locally as "mountain leather." The floors of the caves are covered with large pieces of waste, under which are high-grade zinc and lead ores. Only one cave has been opened that has not produced high-grade ores. The caves do not follow a definite line or formation and do not always occur on faults.

The ore is very spotty or irregular, even in the high-grade sections. Within 10 feet a stope may range in grade from 30 percent zinc and lead to 2 percent zinc and lead. The assays of a typical diamond-drill hole illustrate this:

Footage	Lead, percent	Zinc, percent
90 to 95	2.25	3.8
95 100	-	2.6
100 105	3.10	11.7
105 110	.13	1.7
110 115	2.03	8.1
115 120	9.70	14.8
120 125	8.80	24.4
125 130	3.40	4.8
130 135	14.98	1.9
135 140	3.90	.9
140 145	-	15.9
145 150	3.58	26.6
150 155	1.78	1.7
155 160	1.60	5.8

The ore in this hole averages 3.95 percent lead and 8.9 percent zinc for 65 feet. The average is 2 percent higher in lead and 2 percent higher in zinc than the average grade of ore taken from the mine.

The ore as mined usually assays 5 to 7 percent zinc and 0.5 to 2 percent lead. The zinc concentrate averages 62 to 63 percent zinc with 0.2 to 0.3 percent lead, and the lead concentrate contains 80 to 84 percent lead with 1 to 2 percent zinc.

METHODS OF PROSPECTING AND EXPLORATION

In the Metaline district are large outcrops of the favorable limestone, many of which are mineralized. For years these outcrops received a great deal of attention. Mining was attempted on a few of them, but it was soon realized that the surface showings were very shallow, some having as little as 1 foot of ore.

As the district is very rough and steep and generally covered with overburden ranging in depth to 250 feet, the only method of prospecting that has proved satisfactory is diamond drilling from the surface. Diamond-drill holes are put down vertically, chiefly because it is easier to drive the standpipe through the great depths of gravel and sand. This practice has proved satisfactory also in getting representative cross sections of the underlying limestone horizons.

Sullivan R-21 and R-22 diamond drills powered by 15-horsepower gasoline motors are used on the surface. The R-21 drill has been in operation for 5 years, and except for annual overhauling of the gas engine maintenance cost has been negligible. The drills are equipped with hydraulic feeds. Extra-heavy, 3-inch standpipe is driven to bedrock; a 2 1/4-inch casing is then drilled 10 feet into the bedrock; this is followed with "EX" casing, which is drilled 10 feet beyond the bottom of the 2 1/4-inch casing. "E" rods are used for drilling and are pulled in 20-foot lengths.

Shale is drilled with a bull-nose bit that takes a core about 1/4 inch in diameter. With this bit runs of 20 feet are made between pulls. The footage per 8-hour shift in shale averages approximately 50 feet.

In the limestone, cast-set "E" bits are used with a double-tube core barrel. Runs are from 1 foot to 5 feet in length. The ground is very blocky, and to save core the rods must be pulled whenever the tube blocks.

Drilling is very slow through the ore horizon because of the hardness of the siliceous low-grade ore and the broken character of the ground. Runs usually are from 1 to 3 feet in the ore and 5 feet in the footwall limestone. The holes are stopped when they have entered 25 feet into the gray limestone footwall.

Sullivan Baby Turbineairs with screw feeds and a swivel or double-tube core barrel are employed underground with "E" rods in 5- and 10-foot lengths and with cast "E" bits.

Underground drilling is done to test the walls and large low-grade areas for ore. The holes generally are less than 150 feet in depth and are drilled in every direction and at every angle from horizontal.

All the cores from the drill holes are put in numbered core boxes that will hold 50 feet. These boxes are stored in the core house, where the core is inspected.

The log of each hole is recorded on a log sheet, which also shows the elevation, latitudes and departures, dates drilled, and general information. The log sheets are kept in a loose-leaf folder in a vault in the main office.

Diamond drilling is the principal method of prospecting and exploration. The results show also that it is the cheapest and most reliable method. During a normal year 10,000 feet of holes are drilled; the footage usually increases with increase in metal prices. The diamond-drilling cost during the fiscal year 1938-39 for 9,523 feet was $1.04 a foot.

It should be noted that diamond-drill holes are not used to determine the importance of the ore body. Their entire purpose is to direct the development and mining of the ore sections. The ore discovered by underground drilling usually is opened up by a short tunnel or raise from the nearest stope. This is done as quickly and cheaply as possible. The ore bodies discovered by underground drilling may prove to be very large or small. Because of their irregular shape the size of the ore bodies cannot be determined by underground drilling.

METHODS OF SAMPLING AND ESTIMATING TONNAGE AND VALUE

The only samples from underground that are assayed are diamond-drill cores. If an ore section is at least 3 feet thick and assays 5 percent or more combined zinc and lead the ore body in that vicinity usually is minable.

It is very difficult to estimate tonnages, and several methods that have been applied have failed to give accurate results. The method that is now used is far from accurate in detail, but it gives a useful over-all estimate of tonnage. In a drilled area the greatest dimensions in length and width are multiplied, and the result is the approximate tonnage in that area. For example, an area that is drilled for 1,000 feet in length and 300 feet in width will contain 300,000 square feet of surface area. For each square foot of surface area an average of 1 ton of ore is assumed, making an estimated tonnage of 300,000. In areas of 100,000 square feet or less the estimate usually is very inaccurate, but in larger areas the results have approximated actual tonnage surprisingly.

Although ordinarily ore that assays 5 percent combined zinc and lead is considered to be of commercial grade, mill heads are kept above 6 percent. The value of an ore body cannot be determined until it is completely mined. A stope face may be in 15 percent zinc and lead ore one day and the next show only 5 percent. Accordingly, assay value of the diamond-drill core cannot be used for determining the value of the ore. A hole may show rich ore, yet the area may mine out as a low-grade ore or vice versa. The grade of ore reserves is unknown but is considered to equal the average of the mined areas.

METHODS OF DEVELOPMENT AND MINING

The mine is developed by a 1,000-foot, 7- by 8-foot tunnel known as the Zero level; by a 300-foot, 5- by 10-foot, 80° incline known as the Josephine shaft; by a 1,500-foot, 8- by 8-foot tunnel known as the 500 level; and by a

320-foot, 5- by 10-foot vertical shaft known as the Main shaft. (See figs. 1 and 2).

The collar of the Josephine shaft is at the same elevation as the Zero-level tunnel, and the collar of the Main shaft is at the same elevation as the 500-level tunnel.

The Zero tunnel and the Josephine shaft have not been in use for the past 5 years. At present 80 percent of the ore is hoisted through the Main shaft, and 20 percent is hauled through the 500 level. As shown in figure 2, the portal of the 500 tunnel is 400 feet from the mill, and the Main shaft is 1,200 feet from the mill. The 500 level was driven to intersect the ore body below the 300 level and was used for a main haulage tunnel for the ore on and above the level.

When the extension of the ore body below the 500 level was indicated by surface diamond drilling it was decided to sink a shaft. The shaft was built as near as possible to the center of the ore body, as indicated by the drilling, and at the same time reasonably near the mill.

The Main shaft has two levels - the 700 and the 800. The 800 is the main transportation level; it is provided with ore and waste pockets, one on each side of the shaft.

Shaft Sinking

The Josephine shaft was sunk 100 feet during 1916 and was deepened in 1928 to the 300 level. The Main shaft was sunk during the winter of 1935-36. Rock dimensions of the latter are approximately 12 by 7 feet. The timber is of fir and larch, 8 by 8 inches, with sets at 5-foot centers.

Three crews of miners worked in 8-hour shifts. A crew consisted of two miners, one helper, one top man, and one hoist man. On the day shift a timber man framed and prepared all the timber used. The crews performed whatever operation confronted them, whether drilling, shoveling, or timbering.

A 32-hole V-cut round was used, which broke about 5 feet in depth. Chicago Pneumatic sinkers were used with 1-inch, hollow, hexagonal steel with forged bits. Forty-percent-strength gelatin dynamite was used with electric delay blasting caps, fired from a 22-volt circuit. The broken rock was shoveled into 20-cubic-foot buckets.

A temporary head frame was constructed for the sinking operation; during sinking, the main head frame and ore bins were installed.

Drifting

All tunnels in the mine are called drifts. The drifts are 6 by 7 feet in section and are untimbered; they are given a 0.5- to 1-percent grade in favor of the loads and are provided with a water ditch on one side. Most drifts are less than 100 feet long. They are run in ore if possible regardless of the

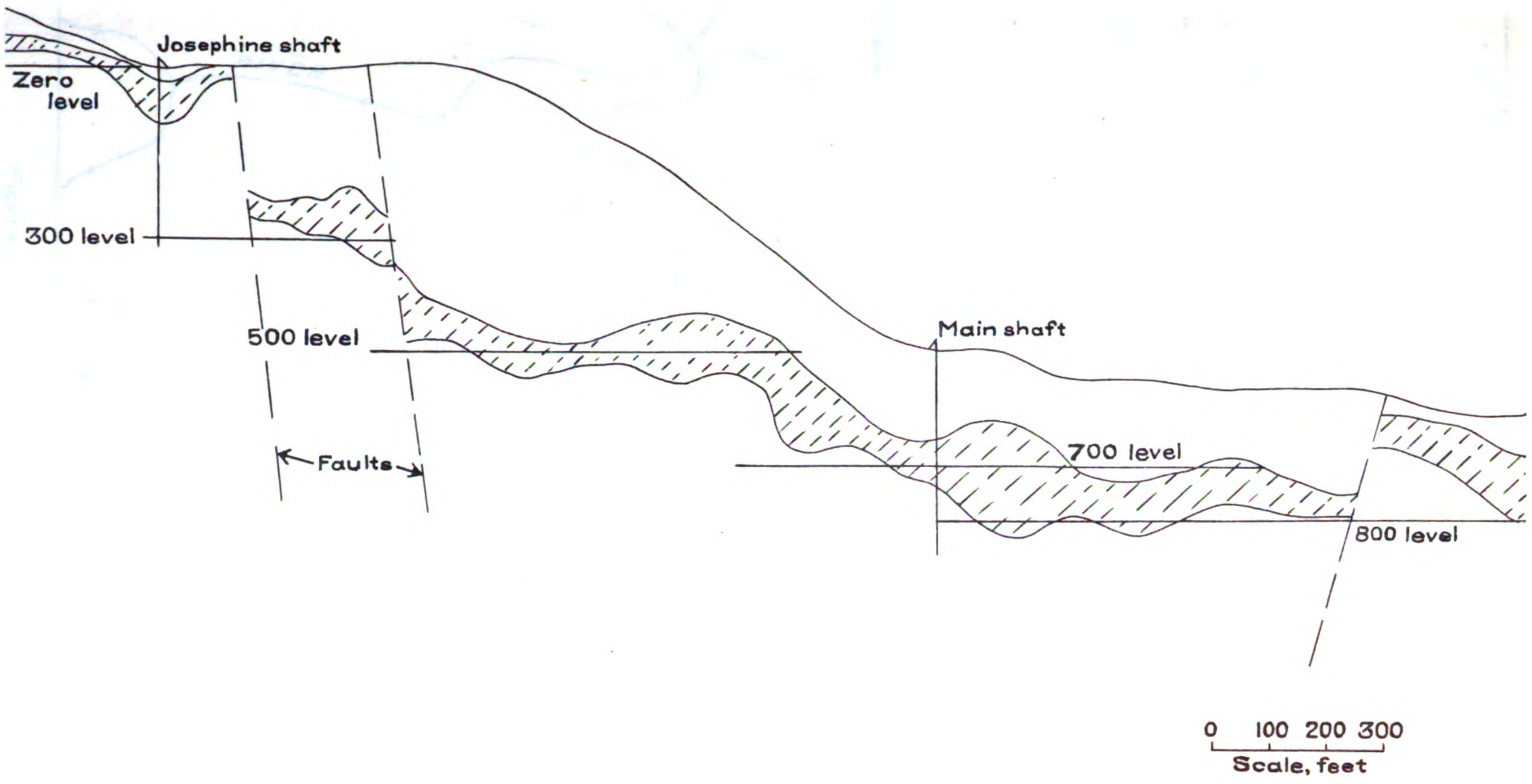


Figure 1.—Section of mined area.

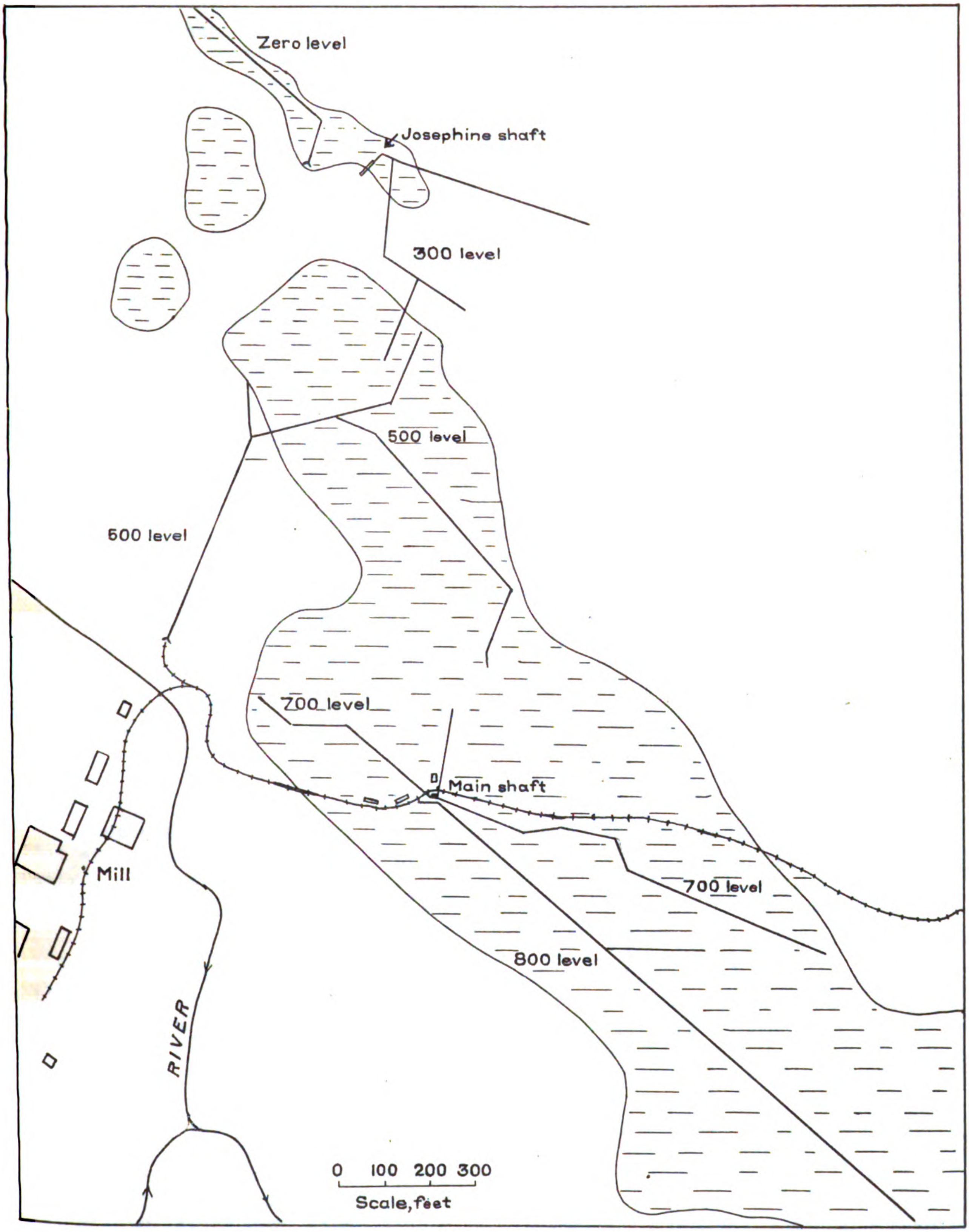


Figure 2.—Plan of mined area.

direction they may take. The track is laid in the center of the drift with 40-pound rails. The main water and air lines are placed on the drift floor and cross under the track wherever necessary.

The following method has now been used on the 800 level for more than 1,000 feet of drifting:

In the face a crew consisting of one miner and a chuck tender drills a 31-hole, box-type, burn-cut round 9 feet deep. The round is loaded with 350 1-1/4- by 8-inch cartridges of Trojan, 50 percent-strength, standard powder. Delay electric blasting caps (No. 0 to No. 9) are fired from a 440-volt line. The round pulls from 8 to 10 feet of ground, depending on the faults at the bottom of the holes. Standard 3-1/2-inch, 7-foot drill columns are used with 3-1/2-foot arms. The drills are 3-1/2-inch, 180-pound drifters. Jack bits are used, with 1/8-inch gage change on 1-1/4-inch hollow round drill steel.

The next shift of two men mucks out the round with a Sullivan overhead air loader. A 2-ton mine car is used and is hand-trammed 800 feet to the skip pocket. After cleaning the face the crew lays the tracks and pipe.

Drifting costs per foot for 757 feet were as follows:

Miners	$0.97
Chuck tenders	.72
Mucker operator	.66
Trammers	.83
Hoisting	.30
Powder	.26
Miscellaneous	.21
Total	5.95

Raising

Raises are run from the drifts to the top of the ore section. These raises seldom are more than 100 feet in height; they are 10 by 5 feet in section and usually are run on a 45° slope. Timbering is seldom done until a raise is complete; then most of the timbering is for chute gates only. In new areas the raises are divided into a manway and ore compartment.

Two miners using 120-pound wet stopers drill a 20-hole, V-cut round, which pulls 6 feet. Jack bits are used on 1-inch, hollow, hexagonal drill steel. A round is drilled and blasted each shift. Trojan powder is used in the holes with a cartridge of gelatin dynamite in each hole to hold in the Trojan powder. The broken rock is loaded by a Sullivan overhead loader or by a scraper until the chute gate has been installed.

Mining Open Stopes with Pillar Support

The limestone formations are very favorable to open-stope methods, as the walls and backs stand unsupported without caving. Areas exceeding 100 feet in all three dimensions have stood opened for 10 years without any sloughing from the walls or backs.

After a drift has entered an ore zone a raise is driven on a 45° slope to the hanging wall of the ore. The hanging wall is determined by the metal content; it is generally blank or very low grade. At the top of the raise sideswiping with a 3 1/2-inch drifter is begun, usually all around the raise. The ore is followed wherever it goes. The drifter is mounted on a 7-foot, 3-1/2-inch column with a 40-inch sliding arm and is installed on one side of the raise. This permits mining the ore in any direction. As the face advances the back is scaled up to solid ground. This operation is checked very closely to eliminate so far as possible the necessity of returning to the back for scaling at a later date.

If the ore goes upward another short raise is started to follow it, or a small shrinkage stope is started with stoper drills. As soon as this overhead ore has been removed the main face is again advanced. (See fig. 3.)

After all walls on the level are barren and the back is in good condition a bench is started from the raise. The bench is 5 to 12 feet high. A 3-1/2-inch drifter mounted on a 90-pound tripod is used for benching. Two or three rows of holes are drilled along the bench to a depth of 8 to 12 feet. After blasting the ore is scraped into the raise, and a new face is prepared for drilling.

The benching operation is continued until the ore stops or the wall of the original stope is reached. If the ore continues beyond the wall a heading is cut under the hanging back into the ore, and a side-swipe face is advanced until the ore stops. (Fig. 4.) The benching, as described, is continued until all the ore has been removed from a stope.

In some areas the ore pitches down into the footwall. Some of these sections are situated so that it is not economical to drive a drift or put in a raise to tap the ore at the bottom. When this condition arises underhand stopes are started; these have been worked very successfully to depths of 40 feet below track levels. A slushing hoist is set on a timber frame, under which a mine car is placed for loading. A cut is made in the floor in front of the frame, and from there it is carried as a regular benching operation, as shown in figure 5. If water is encountered a Chicago Pneumatic sand pump is used. This type of pump has proved very satisfactory for pumping the sand-laden water.

During mine operations the backs are watched very closely. If heavy ground appears a "bar-down man" is called. He is supplied with a 60-foot ladder, long and short bars, spotlight, and other necessary equipment. Work is never carried on under heavy ground, and a mined-out stope is never left with heavy ground hanging in the back or on the walls.

Blasting

Standard-type, V-cut rounds, side-swipe rounds, and benching rounds are used in stopes. Holes range from 5 to 14 feet, depending on conditions. In wet and well-ventilated stopes standard gelatin dynamite is used, whereas in dry and poorly ventilated stopes Trojan 40-percent-strength powder is employed.

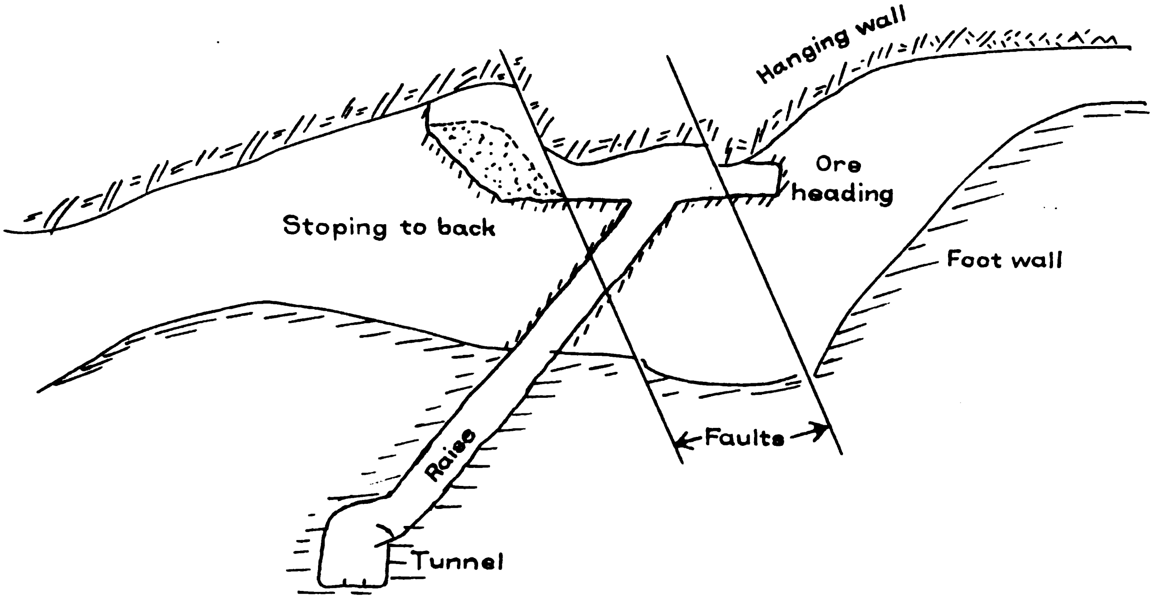


Figure 3.—Cross section showing start of open stope.

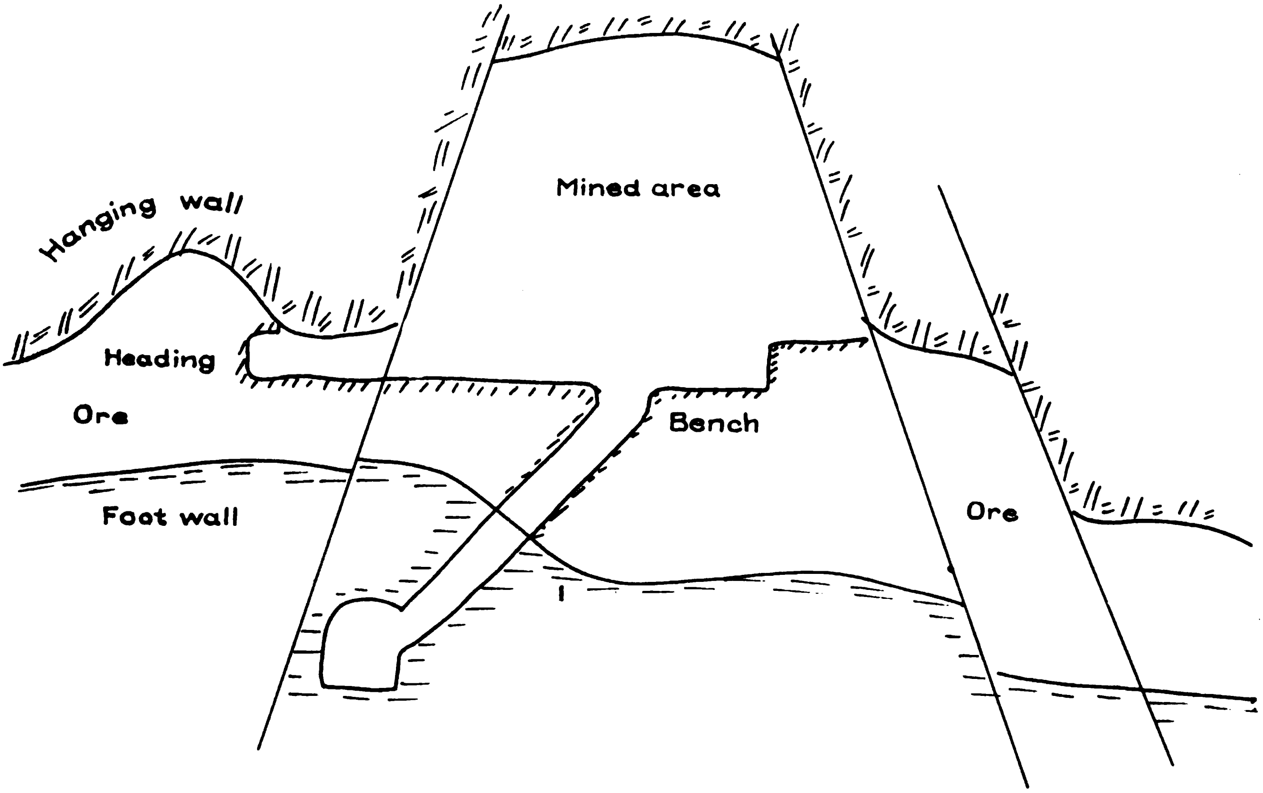


Figure 4.—Cross section of open stope showing benching and heading cut under wall.

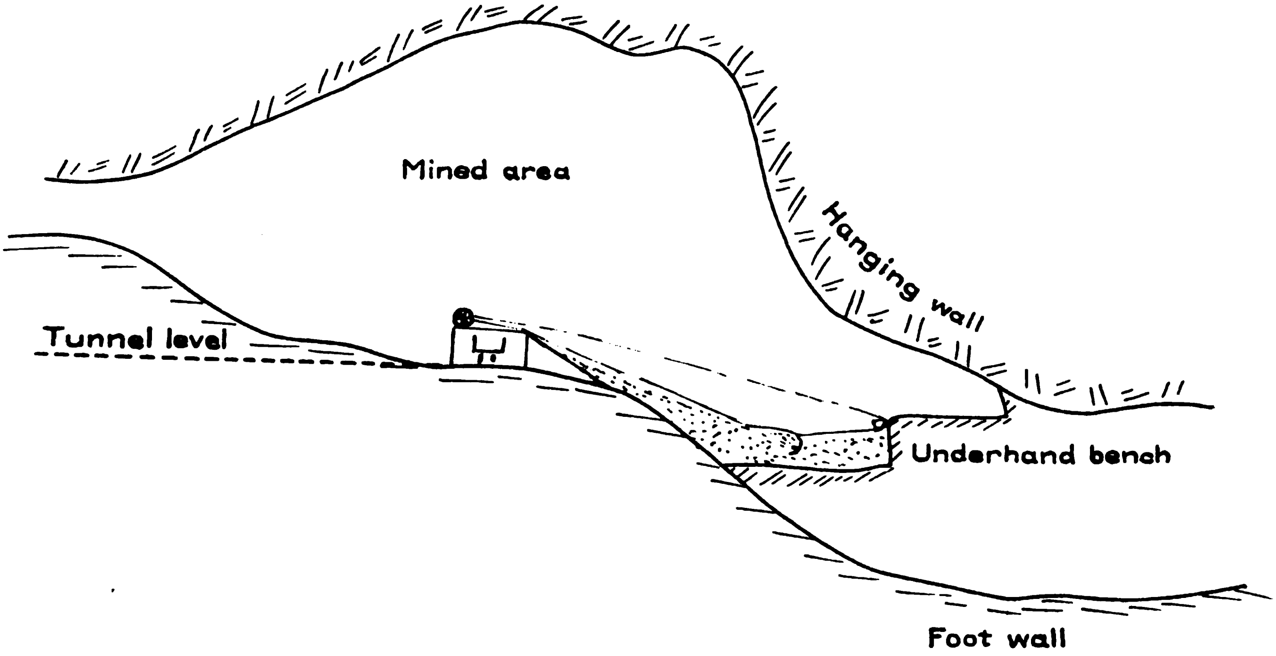


Figure 5.—Timber slide with 15-hp. hoist loading into car, mining from underhand bench.

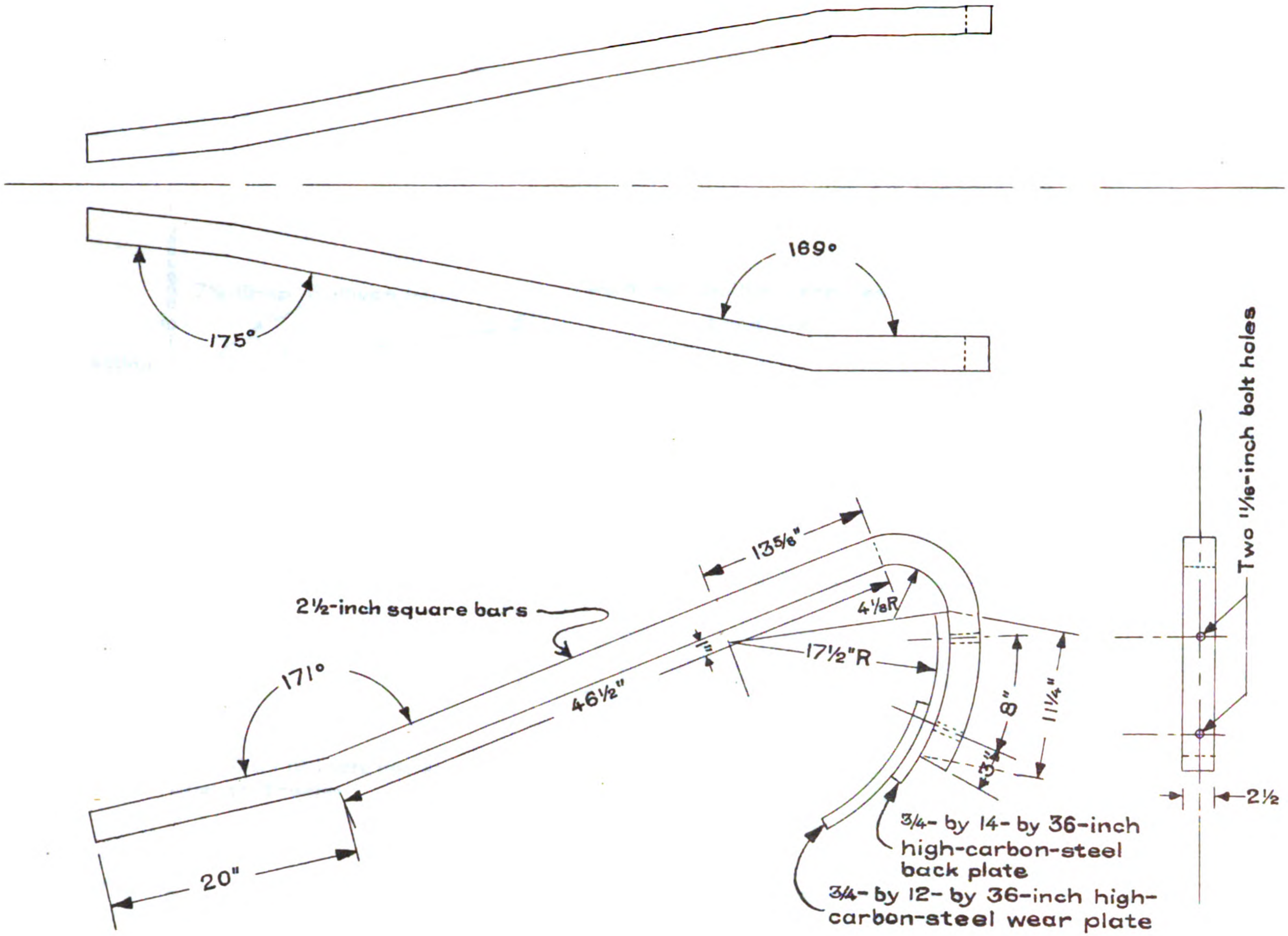
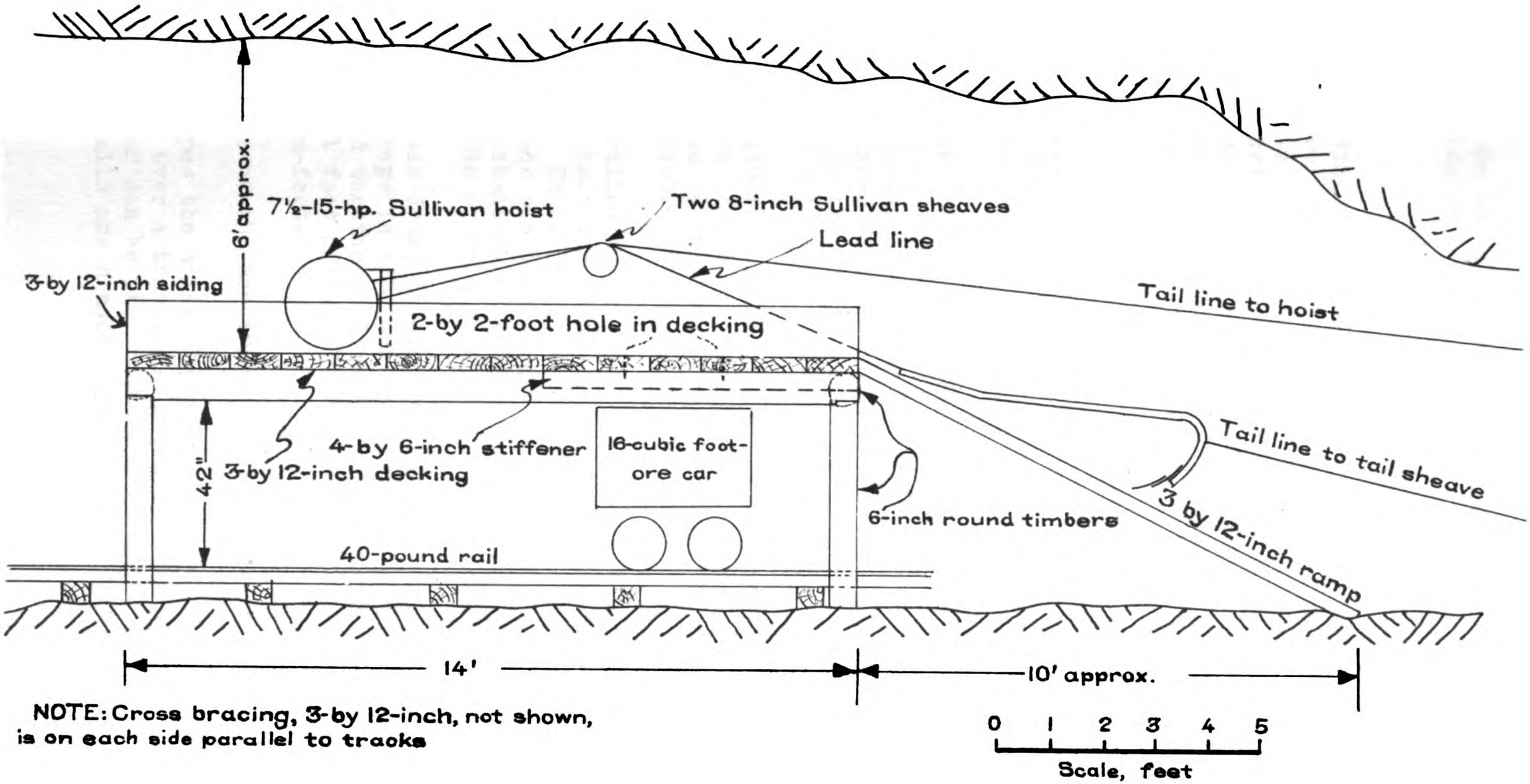

175°
169°
2½-inch square bars
171°
13⅝"
4⅛R
1"
17½"R
46½"
20"
8"
11¼"
3"
¾- by 14- by 36-inch high-carbon-steel back plate
¾- by 12- by 36-inch high-carbon-steel wear plate
Two 1/16-inch bolt holes
2½

Figure 6.—Pend Oreille Mines & Metals Co. slusher-scraper details.



NOTE: Cross bracing, 3-by 12-inch, not shown, is on each side parallel to tracks

Figure 7.—Pend Oreille Mines & Metals Co. mucking slide timber detail.

No. 6 blasting caps and White Bear brand fuses are used in most stoping. Electric delay blasting caps are used in the remaining stopes.

Steel

In all drifting and stoping where 3-1/2-inch drifters are used 1-1/4-inch, hollow, round steel is used. In raises and in some stopes where stopers are used, and with the sinkers, 1-inch, hollow, hexagonal steel is used. Most steel is threaded for detachable bits, which has an advantage over conventional steel, principally because of the difficulty of transporting conventional steel to the stope faces. Costs are approximately the same for the bits, but underground transportation costs are greatly reduced.

Mucking

All broken ore underground is handled by means of Sullivan 15-horsepower, double-drum, electric hoists and by Sullivan 7 1/2-horsepower, air and electric, double-drum hoists. The air hoists are used in areas lacking electric power.

The hoists are placed wherever desirable in the stope and may be moved many times before the stope is mined out. Under low backs the hoists are held in place by 4- to 6-inch poles placed on the hoist base and wedged against the roof. In high stopes four holes are drilled in the floor, two on each side of the hoist; eyebolts are wedged in the holes, and drill steel is passed through the eyebolts over both ends of the hoist.

Power is delivered to the hoists by flexible, rubber-covered cable, hung on the walls wherever possible. In stopes, the cables sometimes are laid over the floor and if close to the face are removed before each blast. A switch box fused for motor protection is placed at each hoist.

Holes are drilled in the face about 10 feet apart, and eyebolts are wedged in. A 3/8-inch chain long enough to go across a full face is passed from eyebolt to eyebolt. Chain hooks are placed on each end of the chain next to an eyebolt to hold the chain in place. An 8-inch, Sullivan, roller-bearing block is hooked to the chain where desired and is held in place by chain hooks; then the pull-back cable or tail rope is put in the block.

On the pull-in drum, 1/2-inch, Seal-type, rope-center, wire cable is used, and on the tail rope is 3/8-inch cable of the same type. When a cable breaks the ends are tied together. A cable is used until it is completely worn out. On the average, 1 foot of cable moves about 10 tons of rock 100 feet, or has a life of 1,000 ton-feet.

Scrapers are of the hoe type. (Fig. 6.)

In most stopes the hoist slushes the ore to a chute. In some stopes timber frames are built over a track, and a hoist is set on the frame, as shown in figure 7. A mine car can be placed under the frame, which has an opening directly over the car. Rails are placed on the incline to protect the timbers from wear.

Where the ore is loaded into cars the hoist operator hand-trams the cars to the main chutes; the distance trammed in stopes is 100 to 500 feet. The slushing operator also sledges boulders in stopes; if there are very large slabs of rock they are drilled and blasted at the end of the shift. Drilling and slushing are not done at the same time in a face or bench, if avoidable, but usually on opposite shifts.

Hoists are operated by one man, who cleans out one to three faces each shift, depending on size and location, and averages 50 tons a shift.

UNDERGROUND TRANSPORTATION

Haulage

The main underground transportation system utilizes battery locomotives, scraper hoists, and hand tramming. On the 500 level ore is loaded from chutes into 2-ton side-dump cars. A train of six cars is handled by a Westinghouse 60-cell battery locomotive. The train unloads at the crusher house.

The 20° incline taps the area above the 700 and below the 500 level. All ores mined in this area are slushed or hand-trammed to the incline. A 25-horsepower Sullivan hoist is at the bottom of the incline. Cables used are 3/4- or 7/8-inch on the pull-in and 1/2-inch on the pull-back. The scraper is larger than those used in the stopes and moves approximately 1 ton of ore per load. The ore is scraped 300 feet down the incline and dumped into the main skip pocket. One operator delivers 250 tons per shift to the skip pocket.

On the 700 level hand-tramming is employed with 1-ton end-dump cars. Chutes are installed along the level for 1,000 feet. One to three trammers are employed; they average 75 tons a shift. The ore is dumped into the skip pocket.

On the 800 level a Mancha battery locomotive hauls four to six 2-ton side-dump cars to the skip pocket.

Chutes are of wood with 36-inch openings. Arc-type steel gates are used. The loader stands at the side of the car to avoid falling rock.

Hoisting

A Sullivan 125-horsepower hoist with a 60-inch drum and a 7/8-inch cable is used in the **Main** shaft. A combination 3-ton self-dumping skip and man cage operates in one compartment. In the other compartment is a counterbalance skip, as shown in figure 8.

The hoist has a lifting capacity of 10,000 pounds at 400 feet per minute. After the mill tonnage was increased and the Main shaft deepened it was necessary to increase the tonnage hoisted through the shaft. The ore load was increased from 4,500 to 6,500 pounds. The weight of the skip plus the ore load then totaled 11,000 pounds. The old skip, which weighs 3,000 pounds, was installed as a counterbalance, thus reducing the average unbalanced load to 8,000 pounds.

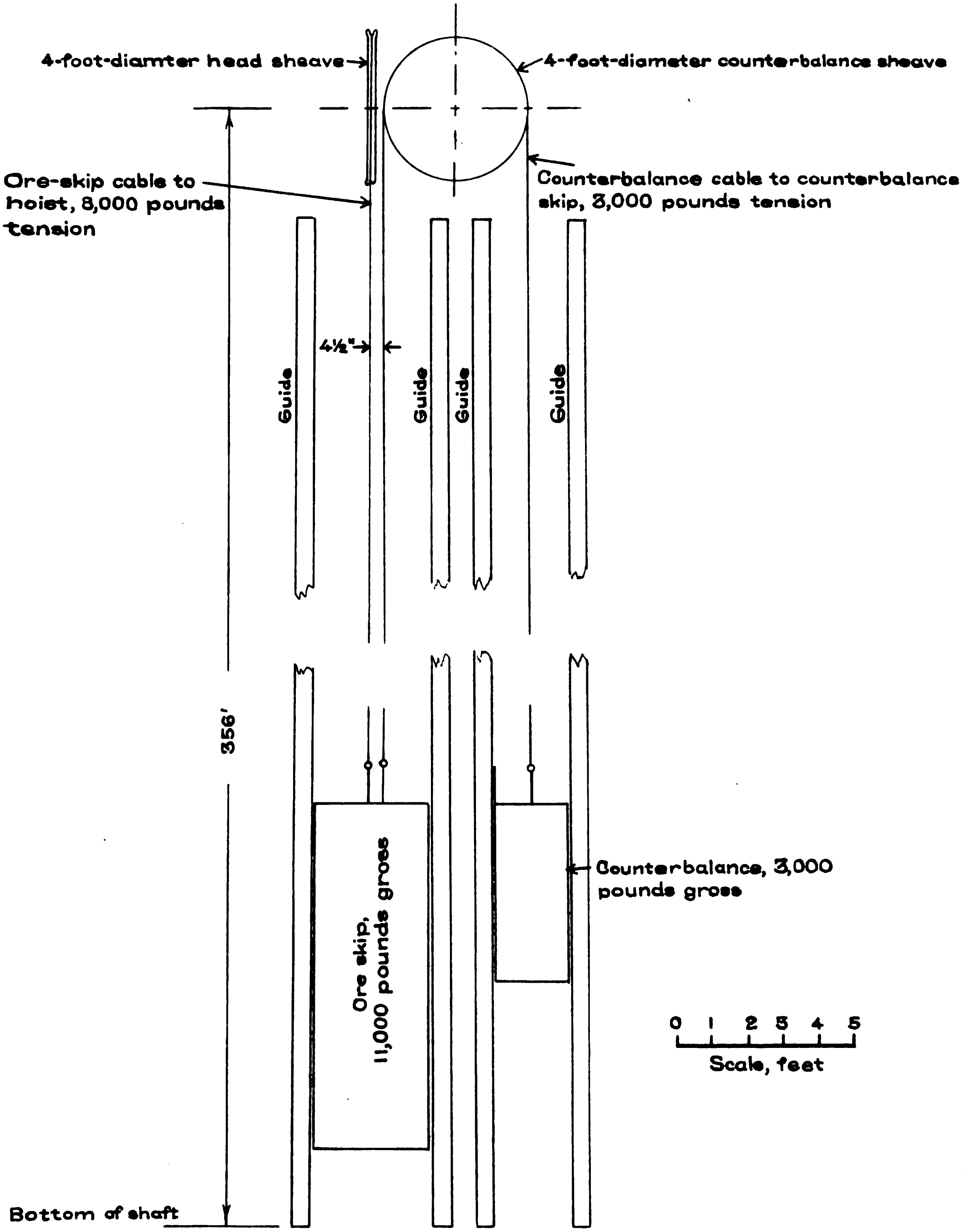

4-foot-diamter head sheave
4-foot-diameter counterbalance sheave
Ore-skip cable to hoist, 8,000 pounds tension
Counterbalance cable to counterbalance skip, 3,000 pounds tension
4½"
Guide
Guide
Guide
Guide
356'
Ore skip, 11,000 pounds gross
Counterbalance, 3,000 pounds gross
0 1 2 3 4 5
Scale, feet
Bottom of shaft

Figure 8.—Pend Oreille Mines & Metals Co. main hoist counterbalance system.

ORGANIZATION

The greatest problem in mining the replacement ores of the Metaline District results from the very irregular shape, distribution, and grade of the ore bodies. At first the mine heads varied greatly, and much waste rock was broken unnecessarily. Moreover, time was wasted in the selection of mining faces each day. This problem was solved by the following method:

Two engineers go through the mine each morning at different times inspecting the faces. The mine superintendent also visits the various faces. At noon the engineers and the superintendent discuss the problem presented in each stope. The faces to be mined are marked, either during the morning inspection or after the subsequent discussion.

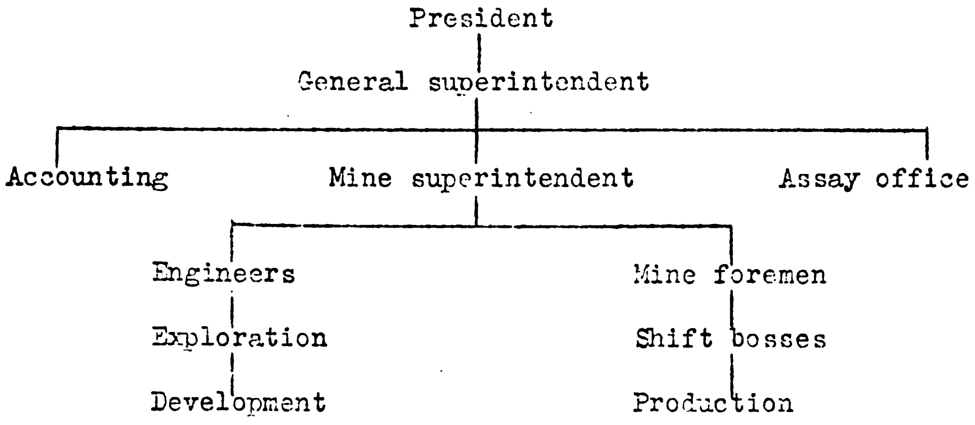
The chief engineer then makes out written orders for each shift boss covering the entire shift. Each miner receives a written order telling him in which stope to work, the location of the round, the number of holes and the type of round to be drilled, the location of the drill to be used, and the name of the man who will assist him.

Orders are also given to the mucking-machine operators instructing them in which stopes they are to work, which faces to prepare for mining, and the number of tons of ore to be delivered to the chutes.

Trammers, also, receive written orders instructing them from which chutes to take ore and the number of tons to be taken. Orders are prepared for two shifts in advance. About 95 percent of the orders are carried out as first given; the rest are changed to meet unforeseen circumstances.

The men go to work as soon as they arrive in their stope, knowing exactly what to do, and no time is lost waiting for orders. The shift boss knows exactly where each man is and the work he is performing.

The staff organization is as follows:



PERCENTAGE OF EXTRACTION

About 95 percent of the ore is removed during the regular mining operations, and about 3 percent is removed during clean-up operations. The remaining ore is left in the pillars, but it is planned to remove it when the stopes are abandoned.

Dilution of the ore by waste and low-grade ores is approximately 15 percent. This dilution cannot be avoided as it is due almost entirely to the characteristics of the ore beds, which include sections of waste and low-grade within the commercial ores. These sections are from a few cubic inches up to 100 cubic feet or more. It is not possible to leave the larger waste sections, as they "tie up" large quantities of ore and leave backs and walls in an unsafe condition. There is no dilution from caving walls or backs in the stopes, raises, or drifts.

COMPARISON OF MINING METHODS USED IN THE DISTRICT

The mining method was established while the property was being developed. There is no other operating property in the district at present. All the mines in the district use the same methods when in production.

WAGE, CONTRACT, AND BONUS SYSTEM

A sliding wage scale fluctuates with the selling price of zinc in East St. Louis. The following hourly wages correspond to the mining costs given in this paper:

Common labor......	$0.53
Chuck tenders.....	.58
Operators.........	.63
Miners............	.68

In all tunnel work a bonus is paid for advances of more than 7 feet per shift.

VENTILATION

The mine is ventilated by natural draft; the air streams reverse from summer to winter on the 500-level tunnel. In summer air enters the Main shaft and the 500 tunnel, rises through the mine, and discharges through the Josephine shaft. In winter air enters through the Main shaft and discharges through the 500 tunnel and the Josephine shaft. During the winter the down draft in the Main shaft causes trouble from the freezing of air and water lines and the forming of ice in the shaft.

FIRE HAZARDS

The surface is heavily timbered, but large areas around the buildings and mine entrances are cleared. Water hydrants and hose houses are situated so that they are readily available for use in case of forest or building fires.

All buildings are protected by Grinnell-type sprinkler and fire-alarm systems. In the mine there is little fire hazard.

SAFETY METHODS

A safety engineer is employed, who is in charge of all safety work. A safety committee consisting of one miner, one surface repairman, and a mining engineer, under the direction of the safety engineer, regularly inspects all underground and surface operations. The committee investigates all accidents and makes a full report with recommendations to the management.

First-aid and rescue instructions are given to key employees and any others who may desire them.

All accidents must be reported at once to the shift boss.

Underground and on the surface all State safety rules are observed and improved whenever possible. "Safety First" posters are placed on bulletin boards, and accident prevention is considered in all operations.

I. SUMMARY OF COSTS

Name: Pend Oreille Mines & Metals Co. Period covered: 1 year.
Tons ore hoisted during period: 227,408.
Mining method: Open-stope-and-pillar.

1. Underground costs per ton ore hoisted:

	Labor	Supervision	Compressed-air drills and steel	Power cost	Explosives	Timber	Other supplies	Total
Development:								
1. In ore ...	$0.056	$0.010	$0.002	-	$0.018	-	$0.057	$0.143
2. In rock								
Mining..........	.340	.035	.040	$0.010	.136	$0.008	.125	.694
Transportation (underground)...	.081	.014	-	.013	-	-	.027	.135
General underground expenses.	.020	.005	-	.001	-	-	-	.026
Surface expense (directly applicable to underground operation)	.006	.009	.002	.001	-	-	.008	.026
Total........	.503	.073	.044	.025	.154	.008	.217	1.024

II. - SUMMARY OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

Name: Pend Oreille Mines & Metals Co. Period covered: 1 month.
Tons ore mined and hoisted: 23,303.
Mining method: Open-stope-and-pillar.

	Mining (stoping)
A. Labor (man-hours per ton):	
Breaking (drilling and blasting)	.37
Timbering and filling	.02
Mucking	.18
Hauling and hoisting	.16
Supervision	.08
General	.12
Total labor underground	.93
Average tons per man per shift	7.93
Labor, percent of total cost	63.6
B. Power and supplies:	
Explosives (pound per ton)	0.86
Total power kw.-hr., kv.-a. per ton	4.72
1. Air compression	-
2. Hoisting	2.48
3. Pumping	.75
4. Ventilation	.14
5. Lighting	.02
6. Scraper hoists	1.33
Supplies and power, percent of total cost	31.4

III. - DETAIL OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

Development: Rock is hard; most development openings are untimbered.

	Drifting	Raising
Size of excavation.....feet	6 by 7	5 by 10
A. Labor (man-hours per foot):		
Breaking (drilling and blasting)	2.28	3.20
Timbering	-	[1] .50
Mucking	1.90	.50
Hauling and hoisting	1.10	2.00
Supervision	.14	.20
Total labor	5.42	6.40
Feet per 8-hour man-shift	1.47	1.25
B. Power and supplies (per foot):		
Explosives (pound per foot)	20	17
Timber	-	-
Total power, kv.-a. per foot	400	400
1. Air compression	Water	Water
2. Hoisting	400	400

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[1] Most raises not timbered. When raise timbered, special crew.